6. Materials in Inventory

Depleted uranium metal billets were once an essential element in the production of weapons-grade plutonium. Today, billets like these are one of the Department of Energy's many types of materials in inventory. Each billet weighs about 1,100 pounds. *Reactive Metals, Inc., Ashtabula, Ohio. June 19, 1984.*

Overview

For 50 years during the Cold War era, the Department of Energy and its predecessor agencies continually acquired, consumed, and produced a wide variety of nuclear and nonnuclear materials to produce weapons and conduct other Department missions. Some of these materials accumulated in significant quantities. When nuclear weapons production was suspended in the early 1990s, the Department had significant inventories of materials on hand. Although the Department still maintains a limited nuclear weapons production capability, the vast majority of these materials are no longer needed to meet current missions. Because of their quantity and characteristics, and the management and disposition challenges they pose, materials in inventory constitute a significant element of the environmental legacy of nuclear weapons production.

In February 1995, DOE launched the Materials in Inventory (MIN) Initiative, a Department-wide effort to improve management, reduce inventories, and reduce costs for materials that no longer have clearly defined or immediate uses. The purpose of this initiative was to assess the Department's inventory, analyze its current management practices, identify its disposition plans, consolidate information on its environmental and safety vulnerabilities, and identify barriers to disposition.[1]

The total amount of materials in inventory is relatively small in comparison with other legacy elements; however, the materials require special management. While some materials in inventory are valuable

[1] *Taking Stock: A Look at the Opportunities and Challenges Posed by Inventories from the Cold War Era, DOE/EM-0275, the report of the MIN Initiative, contains detailed information on the management practices and disposition options for the ten categories of materials in inventory. Taking Stock is the source of the quantitative information provided in this report.*

Categories of Materials in Inventory

NUCLEAR MATERIALS

Natural and enriched uranium includes natural uranium, highly enriched uranium, and low enriched uranium.

Natural uranium is the raw material from which highly enriched uranium and low enriched uranium are produced. It also was formerly used as fuel in some DOE plutonium production reactors.

Highly enriched uranium (HEU) is a form of uranium used as fissile material in nuclear weapons components and in some nuclear reactor fuels.

Low enriched uranium (LEU) is a form of uranium used as fuel for nuclear power reactors, including DOE plutonium-production reactors.

Depleted uranium is a byproduct of the process that produces highly enriched uranium and low enriched uranium. It is used as a raw material to produce plutonium.

Plutonium and Other Nuclear Materials Management and Safeguards System-tracked materials.

Plutonium is a radioactive metal produced from uranium. The isotope plutonium-239 is used as a fissile material in nuclear weapons.

Other NMMSS-tracked materials include nuclear materials such as deuterium, thorium, uranium-233, and americium used for nuclear research and weapons production.

Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated. Spent nuclear fuel also includes uranium and neptunium target materials, blanket subassemblies, pieces of fuel, and debris.

Lithium and lithium compounds are used in the manufacture of nuclear weapon systems, and as raw materials for producing tritium, a radioactive material used in nuclear weapons. While lithium is considered a nuclear material, it is not radioactive.

NONNUCLEAR MATERIALS

Scrap Metal and Equipment includes (1) Scrap metal which comprises worn and surplus metal parts and pieces from old buildings, past maintenance, and renovation activities, and other sources; and (2) equipment which is equipment and machinery used for construction, production, or manufacturing, and associated spare parts and hand tools.

Lead is a dense and malleable metal commonly used to shield workers from nuclear radiation.

Sodium is an easily liquefied metal, primarily used as a coolant in nuclear fast breeder reactors.

Chemicals include a wide variety of materials, including acids, bases, solvents, and gases, used for such diverse purpose as scientific research, chemical processing, manufacturing, water treatment, and building and equipment decontamination.

Weapons components include nuclear weapons parts and sub-assemblies, as well as the tooling, testing, and handling equipment used in the production of nuclear weapons.

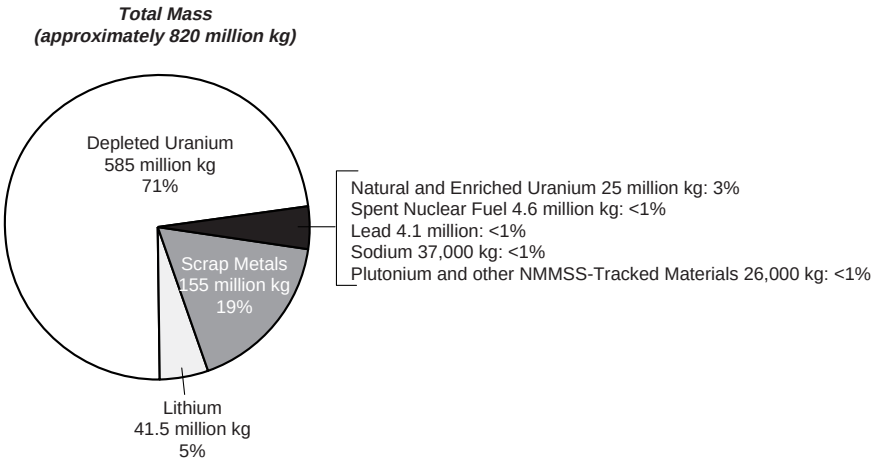
For more detailed information about these materials in inventory, see *Taking Stock: A Look at the Opportunities and Challenges Posed by Inventories from the Cold War Era.*

products, others pose unique risks to human health and the environment or have limited disposition options. Portions of some materials, such as lead, lithium, and scrap metal, have been sold or reused and recycled, but other materials, such as plutonium, can never be released into the public domain.

DEFINITIONS AND CATEGORIES

"Materials in Inventory" are all materials in storage at DOE-owned facilities that are not currently in use, have not been designated as waste, and have not been set aside for national security purposes by the Nuclear Weapons Council (a panel consisting of high level executives from the Departments of Energy and Defense). For nuclear materials tracked by the Nuclear Materials Management and Safeguards System (NMMSS), "in use" is considered to be synonymous with materials in "active" programs, which prescribes use or contemplated use within a two-year period, in accordance with DOE Order 5660.1B, *Nuclear Material Management*. For other materials, "not in use" means the materials have not been used for at least one year and are not expected to be used for the coming year.

Figure 6-1. Summary of Materials in Inventory



Notes:

(1) Data compiled from the Materials in Inventory Report - TAKING STOCK: A LOOK AT THE OPPORTUNITIES AND CHALLENGES POSED BY INVENTORIES FROM THE COLD WAR.

(2) This report does not include quantitative information on chemicals, weapons components, or equipment. In TAKING STOCK chemicals are quantified in various units depending on material; weapons components are quantified in pieces.

(3) SNF quantities are in total mass (kg). The 4,600 metric tons of SNF include about 2,600 metric tons of heavy metal.

(4) Totals may not add due to rounding.

(5) Includes plutonium and HEU from planned nuclear weapon dismantlement at Pantex.

In the MIN Initiative, the Department focused on ten specific categories of both nuclear and nonnuclear materials. These ten categories do not encompass the entire universe of materials in inventory; other materials at DOE-owned facilities fall within this element of the legacy. The ten categories of materials were chosen because they exist in significant quantities; have been the subject of management concerns in the past, or are likely to be of future concern; or are not under a specific DOE program to ensure their comprehensive management. As DOE continues to improve its inventory management systems, it will make further progress in identifying, quantifying and characterizing other materials in inventory.

Key Observations of the Materials in Inventory Legacy

- Over 400 million kilograms of nuclear and nonnuclear materials in inventory have resulted from weapons production. An additional 420 million kilograms of materials in inventory have resulted from nonweapons activities.
- Overall materials in inventory from both weapons and nonweapons activities are present at 44 sites in 19 states.
- Over 85 percent by mass of all materials in inventory is maintained at the Paducah Gaseous Diffusion Plant in Kentucky, the Portsmouth Gaseous Diffusion Plant, in Ohio, and the Oak Ridge K-25 Site, in Tennessee. Almost 80 percent of this material is depleted uranium. When the Fernald site in Ohio and Y-12 site in Tennessee are included, 92 percent (by mass) of all DOE material in inventory mass of this element located within the states of Tennessee, Kentucky, and Ohio.
- Depleted uranium comprises 71 percent of the mass of all materials in inventory; scrap metal makes up 19 percent; lithium represents 5 percent.
- Approximately 38 percent by mass of all materials in inventory is attributable to uranium and lithium enrichment supporting nuclear weapons production. Nearly all of the materials in inventory attributed to nonweapons activities resulted from uranium enrichment.
- Spent nuclear fuel constitutes less than 1 percent of the total mass of DOE's material in inventory; it contains almost all of the radioactivity in the materials in inventory category.

This report incorporated quantitative data from eight of the ten MIN Initiative categories. The two remaining categories, chemicals and weapons components, were quantified in units that could not be converted to mass. The equipment portion of the scrap metal and equipment category also has this limitation.

Maintenance of uranium hexafluoride cylinders. An Oak Ridge worker uses ultrasound to evaluate the effects of corrosion on a steel cylinder containing depleted uranium hexafluoride—the material left over from the uranium enrichment process. The Department of Energy owns over 46,000 cylinders of these enrichment "tails," weighing 10 to 14 tons each. By mass, depleted uranium makes up over 70 percent of the Department's Materials in Inventory. About one-third of the 585,000 metric tons of this material is a result of nuclear weapons production; most of the rest is from enrichment for commercial nuclear power plant fuel. *K-1066-K Cylinder Yard, K-25 Site, Oak Ridge, Tennessee. January 9, 1994.*

RESULTS

Figure 6-1 presents the relative amounts of the eight categories of materials in inventory that have been quantified in terms of their mass. Depleted uranium accounts for about 71 percent of the mass of materials in inventory while scrap metal makes up 19 percent. The other four nuclear materials make up another 9 percent by mass of the materials in inventory, and the remaining two nonnuclear materials make up about 1 percent.

The different categories of materials in inventory contain a variety of radionuclides. As a result, many of the hazards associated with radioactive waste are also present for materials in inventory (e.g., nuclear criticality, radiation and security issues). Four of the materials in inventory categories are inherently radioactive: plutonium and other NMMSS-tracked materials, spent nuclear fuel, natural and enriched uranium, and depleted uranium.

Most of the radioactivity in materials in inventory is in spent nuclear fuel, which contains a broad spectrum of radionuclides with varying half-lives. Materials in the plutonium, natural and enriched uranium, and depleted uranium categories contain a smaller amount of radioactivity and a more limited variety of radionuclides. Radioactivity is also present in some of the nonnuclear materials in inventory due to radiological contamination or activation. For example, some of the lithium shields at Oak Ridge National Laboratory are radioactively contaminated and two have become radioactive as a result of neutron exposure. Large quantities of sodium used for reactor coolant and shielding are also radioactive (approximately 500,000 gallons in DOE inventory, 10 percent of which is classified as MIN). In addition, a

Radioactive scrap metal. Slightly radioactive parts of obsolete uranium enrichment equipment lie in a contaminated scrap-metal yard at Oak Ridge. These 6- and 9-foot wide spun-aluminum disks are categorized as materials in inventory rather than as waste because this metal may be recycled. DOE is recycling some contaminated steel as containers for radioactive waste. Scrap metal constitutes about 20 percent of the Department's Materials in Inventory. *K-770 Contaminated Scrap Metal Yard, K-25 Site, Oak Ridge, Tennessee. January 10, 1994.*

portion of the scrap metal in inventory is radioactively contaminated. In some cases, these radioactively contaminated or activated materials may pose risks to human health and the environment similar to those posed by intrinsically radioactive nuclear materials.

Data on the radioactive content of some materials in inventory are present at the DOE sites that manage the materials. These data have not been compiled at a national level.

Some materials in inventory exhibit hazards due to their chemical properties. For example, uranium hexafluoride, the chemical form of most of the depleted uranium inventory, can produce hydrofluoric acid, a highly corrosive and toxic gas, when exposed to moisture. Materials in inventory with hazardous chemical properties must be stored under special conditions to mitigate these potential hazards.

About half (49 percent) of the materials in inventory legacy has resulted from nuclear weapons production (Figure 6-3). The remaining materials resulted from supplying enriched uranium to the NNPP and commercial nuclear power reactors, various DOE research programs, and other nonweapons activities. About 38 percent of all materials in inventory are attributable to uranium and lithium enrichment for weapons production (Table 6-1). Uranium and lithium enrichment have resulted in nearly all the inventory of depleted uranium (DU), scrap metal, and lithium. Between 5 to 10 kilograms of depleted uranium result for every kilogram of low enriched uranium (LEU) produced, and about 200 kilograms of DU accrue for every kilogram of highly enriched uranium. Similarly, most of the lithium is isotopically depleted in lithium-6, resulting from lithium enrichment, and most of the scrap metal is the result of refurbishment or dismantlement of uranium enrichment plants. Mining, milling, and refining and chemical separation each generated about 4 percent of the materials in inventory.

Table 6-1. Materials in Inventory Categorized by Process

Process	Depleted Uranium (kg)	Low Enriched Uranium (kg)	Natural Uranium (kg)	High Enriched Uranium (kg)	Lithium (kg)	Sodium (kg)	Lead (kg)	Plutonium & Other NMMSS Materials (kg)	Scrap Metal (kg)	Spent Nuclear Fuel (kg)	TOTAL Mass (kg)	Percent
1. Mining, Milling, and Refining	1,600,000	2,680,000	16,700,000			2,780	30,300		9,840,000		31,000,000	4%
2. Enrichment (uranium and lithium)	170,000,000	1,000			41,600,000	320	2,950		97,000,000		310,000,000	38%
3. Fuel and Target Fabrication	4,600,000	3,190,000	406,000	22,000		260	6,270		8,100,000		16,000,000	2%
4. Reactor Operations							525,000		1,600,000	560,000	2,600,000	<1%
5. Chemical Separations	20,000,000	1,400,000	1,500	2,840			77,400	1,710,000	9,400,000		33,000,000	4%
6. Component Fabrication	62,000		68,000	88,000		1,600	5,400	15,000	3,500,000		3,700,000	<1%
7. Weapons Operations				16,700			2,100	21,300	290,000		330,000	<1%
8. Research, Development, and Testing	314,000	17,100	29,000	4,210	1,100	260	939,000	4,000	2,100,000	2,800	3,400,000	<1%
9. Nonweapons - Other	350,000,000	85,500	7,000	18,000	20	566,000	2,400,000	28,700	12,000,000	3,500,000	370,000,000	45%
10. Nonweapons - Naval Support	39,000,000			22,500			127,000		11,000,000	560,000	50,000,000	6%
TOTAL MASS	585,000,000	7,370,000	17,200,000	174,000	41,600,000	571,000	4,110,000	1,780,000	155,000,000	4,650,000	820,000,000	100%
Percent of Total	71%	1%	2%	<1%	5%	<1%	1%	<1%	19%	0%	100%	

Notes:

(1) Data for all materials except SNF compiled from the Materials in Inventory Report – TAKING STOCK: A LOOK AT THE OPPORTUNITIES AND CHALLENGES POSED BY INVENTORIES FROM THE COLD WAR ERA.

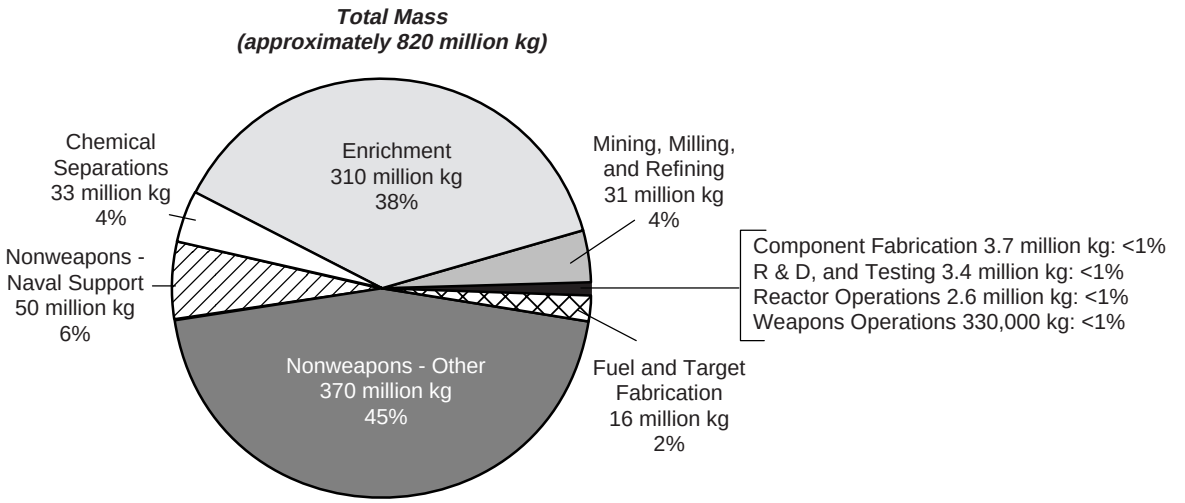
(2) This report does not include quantitative information on chemicals, weapons components, or equipment. In Taking Stock, *chemicals are quantified in various units depending on material; weapons components are quantified in pieces.*

(3) SNF quantities are in total mass (kg). The 4,600 metric tons of SNF include about 2,600 metric tons of heavy metal.

(4) Totals may not add due to rounding.

(5) Includes plutonium and HEU from planned nuclear weapons dismantlement at Pantex.

Figure 6-2. Materials in Inventory Mass Categorized by Process



Each nuclear weapons production process resulted in different categories of materials in inventory (Table 6-1). While uranium and lithium enrichment produced much of the legacy of depleted uranium, scrap metal, and lithium, chemical separation resulted in uranium, lead, and scrap metal, as well most plutonium and other NMMSS-tracked materials. Spent nuclear fuel is the result of reactor operations.

The materials in inventory resulting from nonweapons activities are primarily the result of uranium enrichment for commercial and naval nuclear power reactors. This activity produced most of the inventory of depleted uranium. Nonweapons activities are responsible for most of the Department's lead and sodium, as well as most of the Department's spent fuel, much of which came from the Hanford N Reactor during the period when the reactor produced electricity and fuel-grade plutonium for nonweapons purposes.

The materials in inventory legacy is stored at 44 sites in 19 states (Table 6-2). By mass, over 85 percent of all materials in inventory is maintained at the three gaseous diffusion plants in Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. Almost 80 percent of the total mass of materials in inventory at these three sites is depleted uranium. The Y-12 Plant in Tennessee and the Fernald Environmental Management Project in Ohio also store significant amounts of materials in inventory. Consequently, about 92 percent by mass of the materials in inventory are located in Tennessee, Kentucky, and Ohio.

METHODOLOGY AND DATA

Data Sources

Data on materials in inventory came primarily from a single source, *Taking Stock: A Look at the Opportunities and Challenges Posed by Inventories from the Cold War Era* (January 1996) and the accompanying database prepared as part of the MIN Initiative. The database provided information on the amount of each category of material at each site. For several types of materials, the site-specific amount in each category was further subdivided according to material location, subtype, or form. The database provided information on the mass (in kilograms) of each category of material.

Data on nuclear materials in the database developed under the MIN Initiative came from the Department's Nuclear Materials Management Safeguard System (NMMSS) database, which records nuclear material inventories and transactions by location and individual project, including nuclear

Table 6-2. Location and Mass of Materials in Inventory

Site	Weapons (kg)	Nonweapons (kg)
Paducah Gaseous Diffusion Plant (KY)	170,000,000	250,000,000
Portsmouth Gaseous Diffusion Plant (OH)	89,000,000	110,000,000
K-25 Site (TN)	60,000,000	42,000,000
Savannah River Site (SC)	40,000,000	360,000
Y-12 Plant (TN)	11,000,000	
Fernald Environmental Management Project (OH)	11,000,000	
Hanford Site (WA)	7,000,000	2,900,000
Nevada Test Site (NV)	810,000	
Idaho National Engineering Laboratory (ID)	610,000	3,000,000
Lawrence Livermore National Laboratory (CA)	500,000	
Pantex Plant (TX)	330,000	
Los Alamos National Laboratory (NM)	110,000	
Sandia National Laboratories/New Mexico (NM)	110,000	70
Waste Isolation Pilot Plant (NM)	100,000	
Rocky Flats Environmental Technology Site (CO)	77,000	
Oak Ridge National Laboratory (TN)	76,000	2,500,000
Reactive Metals Incorporated (OH)	71,000	
Grand Junction Projects Office (CO)	21,000	
Sandia National Laboratories/California (CA)	330	
Pinellas Plant (FL)	150	
Kansas City Plant (MO)	83	
Mound Site (OH)	57	25
Other Nonweapons Sites (Various)	—	10,000,000
TOTAL	400,000,000	420,000,000

Notes:
(1) Data completed from the Materials in Inventory Report - TAKING STOCK: A LOOK AT THE OPPORTUNITIES AND CHALLENGES POSED BY INVENTORIES FROM THE COLD WAR ERA.
(2) This report does not include quantitative information on chemicals or weapons components. In TAKING STOCK, chemicals are quantified in various units depending on materials; weapons components are quantified in pieces.
(3) SNF quantities are in total mass (kg). The 4,600 metric tons of SNF include about 2,600 metric tons of heavy metal.
(4) Totals may not add due to rounding.
(5) Naval reactor sites are located in Maine, Washington, Hawaii, Virginia, South Carolina, and California.
(6) Includes plutonium and HEU from planned nuclear weapons dismantlements at Pantex.

materials managed by Nuclear Regulatory Commission licensees, nuclear materials present in DOE-managed spent nuclear fuel, and nuclear materials in the Department of Defense nuclear weapons stockpile. For the MIN Initiative, NMMSS data was reviewed and updated at the site level. Spent fuel inventories came from the Department's Integrated Spent Nuclear Fuel Database.

For this report, the determination of whether individual materials were the result of weapons production or nonweapons activities was made primarily by the site where the material was located. Site location was also used to determine the specific weapons process category associated with the material. For materials at sites performing more than one activity, other descriptive data in the database was usually adequate to assign the material to a nuclear weapons process category or a nonweapons activity.

The depleted uranium inventories at the Department's gaseous diffusion plants were allocated to nuclear weapons and nonweapons activities based on enrichment production records. The scrap metal inventories at the gaseous diffusion plants were allocated using a method similar to that used to allocate waste at the enrichment plants. (see text box, "Uranium Enrichment and Weapons Production" contained in Chapter 3), but accounting for the fact that much of the scrap metal came from plant refurbishments and other activities that took place before most of the enrichment occurred for commercial nuclear power plant fuel.

Spent nuclear fuel storage. Corroding spent fuel elements from Hanford's N Reactor are stored in an unlined concrete pool in the 105 K-West area. Steel grates suspended above the surface of the water allow workers to access all areas of the pool. Corrosion of the fuel elements enables radioactive materials to escape into pool water, posing a hazard to workers and the environment. To reduce the danger, the Department is building a new storage facility for this corroding fuel away from the Columbia River. At this new facility, engineers will dry out the spent fuel and store it in special casks to await storage in a geologic repository. *105 K-West Basin, 100 K-Area, Hanford Site, Washington. December 19, 1993.*

Limitations, Uncertainties, and Assumptions

The quality of the data varies among the ten categories of materials addressed by the MIN Initiative. There is a high level of certainty associated with the Department's inventories of nuclear materials. The Department tracks the quantity and location of nuclear materials very closely through NMMSS. Each site verified the quantity and location of nuclear materials no longer needed for DOE national security purposes during the MIN Initiative. However, there is considerably less certainty regarding the quantity of nuclear materials being used for nondefense programs because information on the current use of nuclear materials is not contained in by NMMSS and the information available from other sources is not as detailed.

The data for nonnuclear materials are generally less exact than those for nuclear materials. The level of certainty associated with data for nonnuclear materials varies for several reasons. Inventory data for some materials has not been compiled at the site level. For example, some sites do not maintain sitewide inventory records of scrap metal, lead, and equipment. As a result, the national inventory records of these materials are incomplete. Equipment and chemicals are difficult to identify and quantify for several reasons, such as their heterogeneity and the lack of a uniform unit of measure. Equipment and chemical quantities are measured in a variety of mass, volume, item count (e.g., number of containers or lots), or dollar value units which cannot be easily combined. Weapons components were reported by pieces and warehouse space requirements rather than mass. As a result, the mass of materials in the equipment and weapons components categories has not been determined under the MIN Initiative, and this report does

not include quantitative information on these categories. Also, the MIN Initiative contains data on only a discrete subset of chemicals identified as "Special MIN Chemicals" that includes chemicals of particular stakeholder concern.[2]

SUMMARY

Nuclear weapons production generated a legacy that encompasses significant amounts of a diverse range of materials. Many of these materials fall into five distinct categories of nuclear materials (depleted uranium, natural and enriched uranium, plutonium and other NMMSS-tracked materials, lithium, and spent nuclear fuel) and five categories of nonnuclear materials (scrap metal and equipment, sodium, lead, chemicals, and weapons components). Data on the mass of material in each category is available, except for equipment, some chemicals, and weapons components. The quality of data available varies by category, although most uncertainties are in the data for nonnuclear materials. In terms of mass, most of the materials in inventory legacy is depleted uranium, a byproduct of the uranium enrichment process. However, the greatest portion of depleted uranium resulted from nonweapons activities. Spent nuclear fuel, generated by reactor operations for both weapons and nonweapons purposes, contains most of the radioactivity in the Department's Materials in Inventory.

In addition to the ten categories of materials in inventory identified by DOE, there may be other categories of materials that have not yet been defined or studied. However, most of the materials with major management and disposition concerns appear in the ten identified categories.

Materials in Inventory Data Issues

Mass data on eight categories of materials in inventory are included in this report. Data on the mass of equipment, weapons components, and most chemicals are not included.

In general, data on nonnuclear material categories do not have the same level of certainty as data on nuclear materials.

There may be other materials that meet the definition of materials in inventory in other categories in addition to those studied by the MIN Initiative. Data on the quantities of these materials have not been compiled.

The nuclear and nonnuclear materials covered by this report pose significant management and disposition challenges to the Department because of their quantity and their unique physical, chemical, and radiological characteristics. Current DOE plans include recycling some materials such as lead and scrap metal, and selling some uranium scrap metal and lithium to commercial industries. DOE plans to dispose of spent fuel in a geologic repository pursuant to the Nuclear Waste Policy Act. For other materials, particularly plutonium, disposition is being determined through the National Environmental Policy Act process.

[2] *The MIN Initiative obtained information on the masses of all reported "Special MIN Chemicals," a subset of this MIN category which includes chemicals of particular stakeholder concern. This report does not include this inventory data as it does not give a complete picture of this category. For more information, see* TAKING STOCK.

APPENDICES